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Wildlife Implications of FRDA Northern Interior Research: Summary and Recommendations

by
Susan K. Stevenson

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For additional copies and/or further information about the Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II, contact:

Forestry Canada
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C. V8Z 1M5
(604) 363-0600

or

B.C. Ministry of Forests
Research Branch
31 Bastion Square
Victoria, B.C. V8W 3E7
(604) 387-6719

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1 INTRODUCTION

Treatments that encourage conifer growth also affect wildlife and fish habitat. In turn, some wildlife species affect conifer growth. Both sets of impacts, though potentially severe, are not well understood.

The Canada-British Columbia Forest Resource Development Agreement (FRDA) has funded several projects in the northern Interior that focus on wildlife and fisheries concerns related to forest activities. In addition, some of these projects not focussed specifically on wildlife have, nevertheless, yielded results that have implications for integrated resource management. The objectives of this review were to:

1. summarize and interpret results of the FRDA northern Interior research projects that have implications for wildlife and fisheries;
2. assess the potential of existing FRDA northern Interior field projects to provide useful information on the long-term effects of backlog reforestation on habitat values, and make recommendations for continued monitoring; and
3. assess the potential of these field projects to be demonstration areas for forestry/wildlife interactions, and make recommendations for development of demonstration areas.

To meet these objectives, I reviewed reports submitted by January 1991 and contacted researchers for additional information. Within the limits of time and budget, I also visited field sites that seemed to offer potential as demonstration areas.

2 EFFECTS OF BACKLOG REFORESTATION TREATMENTS ON HABITAT VALUES

The goal of backlog reforestation is to convert forest land which is presently NSR (not satisfactorily restocked) to full stocking with silviculturally acceptable trees. In the long term, backlog reforestation as it is currently practised tends to replace highly productive habitats with habitats that are less productive for many wildlife species. In the short term, the different methods used to achieve reforestation affect the structure and composition of the vegetation differently, and thus vary in their effect on wildlife.

In northern interior British Columbia, NSR sites support early seral plant communities (herb or shrub complexes), pure aspen forests, mixed deciduous stands, overstocked or stagnant pine types, or mixed deciduous/conifer stands that resulted from wildfire or IU (intermediate utilization) logging (Butt 1988). Most of these sites tend to be rich in food and cover plants for wildlife. As well, many are high in structural diversity and include special habitat features, such as snags and fallen trees. In contrast, the immature, closed-canopy coniferous stands that result from current reforestation prescriptions tend to be less productive for wildlife (Stevenson and Hatler 1989). Regardless of method, the major long-term impact of plantation silviculture on wildlife is to reduce the extent and duration of productive habitats.

However, silviculture need not be directed exclusively at timber production. Silviculturists are increasingly viewing their discipline as "applied forest ecology — a means for protecting and enhancing range, wildlife, water, and soil resources, as well as timber crops . . . the manipulation of forest vegetation for human purposes" (Wenger 1984:414). Taking this broad view, silviculturists can apply their expertise to creating stands that have the necessary habitat elements for meeting objectives for wildlife management as well as producing fibre.

Successful application of management to meet objectives for wildlife and timber production depends on our understanding the relationships among silvicultural treatments, habitat attributes, and wildlife populations. At present, most managers' understanding of those relationships is inadequate. Because the findings compiled in this report are drawn from a small number of studies — most of which were oriented to reforestation — what information we do have is fragmentary. Future silviculture projects that incorporate wildlife assessments into the study design will contribute more to our understanding of habitat relationships.

2.1 Prescribed Fire

Fire has the potential to affect a variety of site characteristics that are important to wildlife and in some cases, to fish. It can alter the structure and nutrient status of the soil; the moisture regime of the site; the structure, species composition, and nutrient status of the vegetation; and the amount and physical characteristics of woody material. Many boreal wildlife species are adapted to fire, and flourish during the early successional stages that follow.

The FRDA northern Interior projects that have provided information on vegetation response and wildlife abundance after prescribed fire are discussed below.

2.1.1 Effects on vegetation structure

The effects of fire vary among sites. On mesic and submesic sites in the Sub-Boreal Spruce (SBS) zone, the original plant species tended to be replaced rapidly by fireweed (*Epilobium angustifolium*) and other species characteristic of disturbed areas. Fireweed also invaded on wetter sites, but the original herbs and shrubs were more likely to resprout. That difference may have resulted, in part, from the generally greater fire intensity on drier sites. The rate of revegetation after fire was generally faster on wetter sites than on dry sites (Hamilton and Yearsley 1988 [FRDA Project 1.08]).

Fire reduces total vegetation biomass, though only for a short time. A herbicide spray-and-burn treatment of Engelmann Spruce-Subalpine Fir zone (ESSF) brushfields at the site of FRDA Project 1.17 reduced vegetative cover from 58 to 4% after 2 months, but it returned to 50% 1 year later. Vegetation height was reduced from 90 to 14 cm, but returned to 50 cm a year later.[1] At an IU logging site in the Wet Cool subzone of the Sub-Boreal Spruce zone (SBSwk) (FRDA 1.20), total vegetation volume was lower than before treatment in all cases during the first growing season after prescribed burning. During the second growing season, vegetation volume returned to pretreatment levels in the broadcast burn and windrow-and-burn treatments, but was still reduced in the spray-and-burn treatment.[2] At the FRDA 1.13 site, herbs dominated during the first two growing seasons after dense lodgepole pine stands were burned. There were no obvious trends in total biomass as a function of site preparation treatment or fire severity.[3]

2.1.2 Effects on individual plant species

Species composition after fire of a given type and severity depends on the pre-existing vegetation, the presence and survival of banked seeds, and the availability and establishment success of off-site seeds (Hamilton and Yearsley 1988). Table 1 shows the response to fire of selected species important to wildlife, as observed in FRDA projects. The vegetation responses reported in Table 1 vary with climate and site characteristics; importance of plant species to wildlife is also variable. Hamilton and Yearsley (1988) presented a more detailed discussion of vegetation responses, comparing their observations in the SBSj1 (now classified as a variant of the SBSwk) with information reported in the literature.

2.1.3 Responses of wildlife

No FRDA northern Interior projects have specifically investigated the responses of wildlife to fire. However, as a means to developing a monitoring methodology (FRDA 1.49), D. Hatler recorded wildlife occurrence and activity at the FRDA 1.13 site. Located in the SBSe1 (now classified as a variant of the Moist Cold Sub-Boreal Spruce zone [SBSmc]), the site had initially supported a dense

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1 Sutherland, C. 1990a. Treatment development for rehabilitating ESSF backlog brushfields: third-year file report. B.C. Min. For., Williams Lake, B.C. Unpubl. report.

2 Taylor, S.W., B.C. Hawkes, R.H. Silversides, and M.G. Weber. 1990. Some initial effects of prescribed fire and mechanical site preparation on the seedling environment and establishment on a backlog NSR site in Central Interior B.C. For. Can., Victoria, B.C. Unpubl. report.

3 Blackwell, B., M.C. Feller, and R. Trowbridge. 1989. Some ecological effects of windrow and broadcast burning dense lodgepole pine stands. B.C. Min. For., Smithers, B.C. Unpubl. report.

TABLE 1. Response of wildlife forage species to prescribed fire, as reported in FRDA northern Interior projects

Forage species	Wildlife species[a]	Response to fire[b]			Comments
		Germination from banked seeds	Germination from off-site seeds	Resprouting from roots or rhizomes	
Epilobium angustifolium Fireweed	Moose, deer, small mammals		X	X	Peak abundance in SBSwk 3–6 years after burning; has declined somewhat by 9th year. Biomass tends to increase as fire severity increases.[c] Post-fire abundance lower after spray-and-burn than burn only.[d]
Lonicera involucrata Black twinberry	Bears, moose, birds			X	May be killed by severe burns. Post-fire abundance lower after spray-and-burn than burn only.[d]
Populus tremuloides Trembling aspen	Moose, mule deer, beaver, porcupine, snowshoe hare, small mammals, ruffed grouse, elk			X	No apparent difference in abundance after MSP or burning in the SBSwk.
Ribes spp. Gooseberries and currants	Bears, birds	X			Abundance greatest 3–6 years after burning in SBSwk. No difference after MSP or burning.
Rubus idaeus Red raspberry	Birds, small mammals, bears, deer, snowshoe hare	X		X	Abundance increased during first 10 years after fire. No apparent difference in abundance after MSP or burning in the SBSwk. Post-fire abundance higher after spray-and-burn than after windrow-and-burn.[d]
Rubus parviflorus Thimbleberry	Bears, birds, small mammals	X		X	In SBSwk, greatest abundance 1–5 years after burning on mesic/submesic sites; persists longer on moister sites.
Salix spp. Willow	Moose, mule deer, white-tailed deer, mountain goat, elk, beaver, small mammals, birds		X	X	Abundance increased during first 10 years after fire. No difference in abundance after MSP or burning in the SBSwk.
Sambucus racemosa Red elderberry	Moose, deer, elk, porcupine, small mammals, birds, bears	X		X	Common by 3–4 years after fire in SBSwk.
Vaccinium membranaceum Black huckleberry	Bears, elk, moose, birds, snowshoe hare, small mammals			X	No increase in abundance during first 10 years after fire in SBSwk. Abundance lower after fire than after MSP.

[a] Haeussler and Coates 1986; Balfour 1989; D. Hatler, pers. comm., Jan. 1991; D. King, pers. comm., Jan. 1991; B. McLellan, pers. comm., March 1991.
[b] From Hamilton and Yearsley (1988), except as noted.
[c] Blackwell, B., M.C. Feller, and R. Trowbridge. 1989. Some ecological effects of windrow and broadcast burning of dense lodgepole pine stands. B.C. Min. For., Smithers, B.C. Unpubl. report.
[d] Taylor, S.W., B.C. Hawkes, R.H. Silversides, and M.G. Weber. 1990. Some initial effects of prescribed fire and mechanical site preparation on the seedling environment and establishment on a backlog NSR site in Central Interior B.C. For. Can., Victoria, B.C. Unpubl. report.

(14 000–26 000 stems per hectare) stand of lodgepole pine. The silviculture study investigated the effects of two treatments — mechanical knockdown of trees followed by broadcast slashburning, and mechanical knockdown followed by windrowing and burning — and four levels of fire severity.[4]

The site was dominated by herbs during the first two growing seasons after burning. There were no obvious trends in either total biomass or relative proportions of shrubs, herbs, and mosses/lichens as a function of site preparation treatment or fire severity. However, some differences in the biomass of individual species did occur: fireweed tended to increase as fire severity increased, but twinflower (*Linnaea borealis*) tended to decrease.

Figure 1 shows the distribution of wildlife sign at the study area in August/September 1989, 3 years after treatment. Data for all burn treatments are grouped, and the control areas are adjacent, unlogged pine stands that resulted from a 1932 fire (F. Milinazzo, pers. comm., Oct. 1990). The control area appeared to support much more wildlife activity than the treatment area. Moose sign was observed about four times as often in the control area as in the treatment area. Signs of hare, grouse and squirrel were consistently present in the control areas, but rare (hare) or not found (grouse and squirrel) in the treatment area (D. Hatler, unpubl. data). The herb-dominated site was evidently not favourable habitat for those species, which are more characteristic of later successional stages.

Figure 2 shows the results of small mammal trapping during the same period. While the occurrence of small mammals was only a little lower in the treatment area than in the control, the main difference between the two areas was in species composition. Southern red-backed voles (*Clethrionomys gapperi*) were the dominant species in the unlogged pine, but were not found in the treatment area. Deer mice (*Peromyscus maniculatus*) and field voles (*Microtus* spp.) were rare or absent in the control areas and more abundant in the treatment area. Shrews (*Sorex* spp.) were present in low numbers throughout.

Those results differ somewhat from those of Sullivan,[5] who studied small mammal populations after herbicide applications in the Very Wet Cool SBS (SBSvk) and the Wet Cool SBS (SBSwk) subzones (FRDA 1.34; see Section 2.3.3). In the FRDA 1.34 study area, red-backed vole and deer mouse populations exhibited partial or full recovery in the 2nd year after treatment. Two important habitat differences may account for these differences in population response, especially of southern red-backed voles. First, more woody debris was present at the FRDA 1.34 sites than at the 1.13 site, even though the 1.34 sites had also been burned after logging (D. Hatler, pers. comm., Feb. 1991). Second, the 1.13 site is relatively dry, and patches of exposed mineral soil were still noticeable in fall 1990, four years after burning. Overall, much less cover was present at the FRDA 1.13 site than at the 1.34 sites.

Similarly, at the FRDA 1.17 site, spring-planted seedlings sustained less damage from snowshoe hares in the brown-and-burn treatment area than in any other. Apparently the reduced security cover in the brown-and-burn treatment area discouraged the hares.[6]

2.2 Mechanical Site Preparation

Mechanical treatments for backlog reforestation are aimed at clearing the existing vegetation and preparing microsites suitable for planting. Those objectives are sometimes accomplished in two steps, and sometimes in one. The effects of mechanical treatments on wildlife were not studied directly in any of the projects, but the information provided about vegetation impacts has implications for wildlife management.

2.2.1 Brush clearance

Where competing vegetation is tall, it may be cleared as the first step toward reforestation. Clearing often results in vigorous resprouting of deciduous trees and shrubs, some of which are valuable forage species. Since the timing of the treatment affects the response of the vegetation, that information can be used to control the degree of resprouting to meet management objectives.

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4 Blackwell *et al.*, 1989.

5 Sullivan, T.P. 1990a. The impact of herbicide use on small mammal populations in sub-boreal spruce forest. Applied Mammal Research Institute, Langley, B.C. Unpubl. report.

6 Sutherland, C. 1990b. Treatment development for reforesting ESSF backlog brushfields. Presentation to NITAC, Jan. 1990.

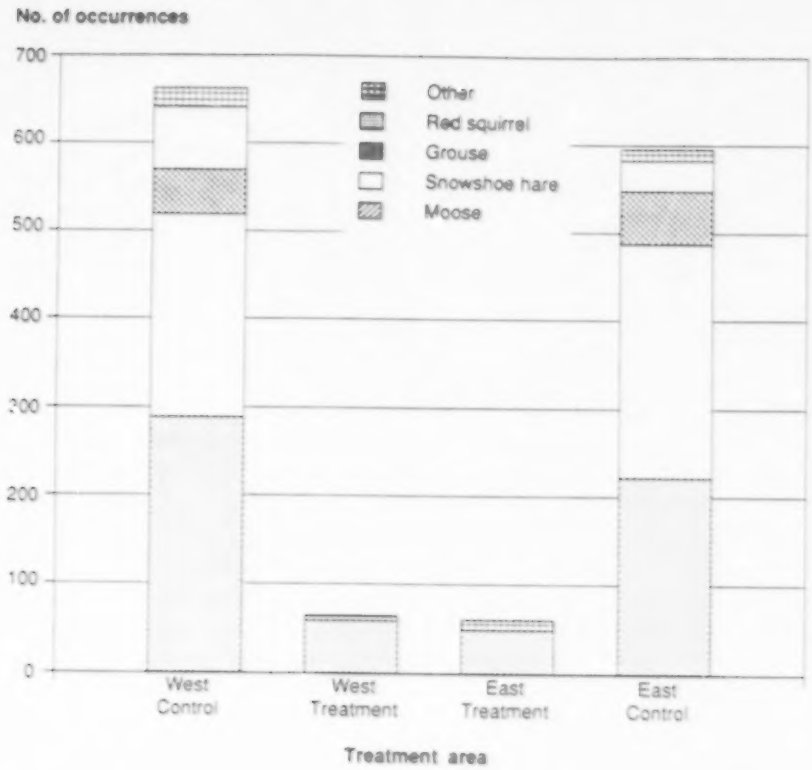

FIGURE 1. Distribution of wildlife sign at the FRDA 1.13 study area 3 years after burning (D. Hatler, unpubl. data).

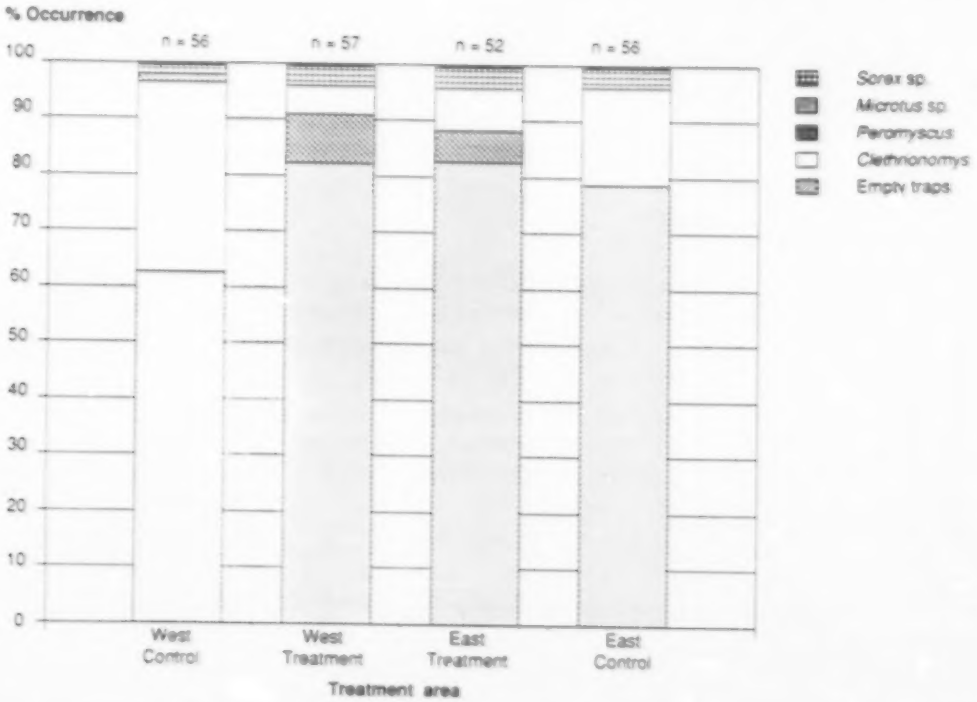

FIGURE 2. Percent occurrence of small mammals in snap traps at the FRDA 1.13 study area 3 years after burning (D. Hatler, unpubl. data).

At a trembling aspen site in the Boreal White and Black Spruce (BWBS) zone (FRDA 1.02), winter shearing with a V-shaped shearing blade was compared to fall clearing with a brush blade. The summer after treatment, the winter-sheared plots were dominated by balsam poplar (*Populus balsamifera*) and trembling aspen (*P. tremuloides*), while reedgrass (*Calamagrostis* spp.) and fireweed occupied the growing space not used by poplars on the fall-cleared plots.[7] Winter shearing resulted in more than 50 000 shoots per hectare of *Populus* spp., more than twice as many as in the fall-cleared area. Greater removal of root propagules during fall clearing was thought to account for the difference. In general, winter shearing tends to snap off stems near the base, while fall clearing with a brush blade is more likely to uproot trees and cut through underground suckers (Butt 1988).

At the FRDA 1.20 site in the SBSwk subzone, trembling aspen increased above pretreatment levels by sprouting from stumps cut with a brush blade in June.[8]

Willows (*Salix* spp.) are well known to resprout vigorously after brush cutting. An area that was densely covered with large willows was cut with power saws in 1986. Two years later, willows over 2.5 m tall covered 20% of the site (Porter 1990).

Bancroft and Butt (FRDA 1.33) studied the response of willows to manual severing at various times during the growing season.[9] One year after treatment, plants severed on July 6 were much shorter than before treatment and slightly reduced in vigour. They also had slightly more live stems per clump than before treatment. Plants severed on July 28 or September 7 were only slightly shorter than before treatment, exhibited no loss of vigour, and had more than twice as many live stems per clump than before. That difference in response was probably related to the annual storage cycle of carbohydrate reserves. Phenological data showed that stem and leaf growth were still in progress on July 6, but had been completed by July 28.

Repeated cutting of vegetation can greatly inhibit its future productivity. At the Archie Road (North) site in the SBSvk subzone (FRDA 1.16), understory vegetation was clipped three times each summer during the first 2 years after hybrid white spruce (*Picea glauca* x *engelmannii*) and lodgepole pine (*Pinus contorta*) were planted. This treatment suppressed the competing vegetation for several years, and resulted in the best conifer performance on the site.[10] Seventeen years after the last treatment, thimbleberry (*Rubus parviflorus*) is noticeably lower in the clipped area, and hardwoods are rare. These observations suggest that where wildlife objectives or other environmental concerns preclude extensive vegetation control, repeated cutting with a brush saw immediately around seedlings may be effective. Additional research is required to determine costs and optimum scheduling for this sort of treatment in various ecosystems.

2.2.2 Scalping

Scalping, or screefing, removes the duff and humus layers and exposes the underlying mineral soil. The purposes of scalping are to warm mineral soils and reduce competing vegetation. Methods of scalping include blade scarification, V-plowing, ripper plowing, brush blading (to create windrows or spot piles), disc trenching, and patch scarification (Butt 1988).

By removing the roots and rhizomes of competing species and a large part of the stored seed pool, scalping initially reduces vegetation abundance. The effect may be short-lived, as the exposed mineral soil provides an excellent seedbed for light-seeded species. The treatment may also stimulate the development of vegetation that reproduces by suckering.[11]

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[7] Herring, L.J. and R.A. Letchford. 1987. Assessment of treatment options for reforestation of NSR backlog in the boreal region of B.C. EP 986.00. B.C. Min. For., Prince George, B.C. Unpubl. report.

[8] Taylor *et al.*, 1990.

[9] Bancroft, B.G. and G. Butt. 1990. The effects of different rates and timing of glyphosate on willow species in moose winter range in the Sub-Boreal Spruce Zone: establishment report and first-year results. Madrone Consultants, Ltd., Victoria, B.C. Unpubl. report.

[10] McMinn, R. 1990a. Archie Road (North) demonstration plot. Unpubl. tour guide.

[11] Brand, D.G. and M. Penner. [n.d.] Interactions between vegetation competition, nutrient availability, soil surface modification and the early growth of planted spruce. Can. For. Serv., Chalk River, Ont. Unpubl. report.

At the FRDA 1.02 site in the BWBS zone, plowing or discing after fall clearing initially reduced *Populus* spp. by about half. Plowing effectively depressed the regrowth of reedgrass; the mineral soil of the furrows was apparently inhospitable to rhizomes or seeds during the first two growing seasons after plowing.[12] Cover of grasses (primarily reedgrass) was lower in disc-trenched than non-trenched treatments at the FRDA 1.20 study area in the SBSwk.[13]

Fireweed is well adapted to invade scalped sites. At the FRDA 1.17 site in the ESSF zone, scalping initially decreased fireweed cover from 19 to 2%, but it returned to 8% after 1 year and 15% after 2 years.[14] At the 1.02 study area, fireweed aggressively colonized the plowed furrows.[15] Other species that invaded scalped areas within the first two growing seasons were prickly rose (*Rosa acicularis*) at the 1.02 site,[16] and red raspberry (*Rubus idaeus*) at the 1.20 site.[17]

Shrubs and trees, some of which are important to wildlife, may be stimulated by scalping. For example, an area burned by wildfire in 1961 was disced in 1983 and 1984. The large willow crowns already present on the site resprouted and, by 1988, Scouler's willow (*Salix scouleriana*) up to 2 m tall covered 22% of the site (Porter 1990).

At some sites, the advantages to seedlings from scalping may be offset by the increased colonization of hardwoods. For example, at a FRDA 1.16 site in the SBSvk subzone, scalped areas were invaded by cottonwood, birch (*Betula papyrifera*), and trembling aspen more than untreated areas were. Fourteen years after planting, height, diameter, and volume of spruce and pine were significantly greater in untreated areas than scalped areas.[18] Initially, poor access of the roots to nutrients probably limited conifer growth in the scalped areas; hardwood competition did not become a factor until 5–10 years after planting (R. McMinn, pers. comm., Feb. 1991).

2.2.3 Inverting

The purpose of inverting is to increase heat penetration into the soil, while at the same time conserving organic matter and nutrients. It is accomplished by any of several mounding machines, moldboard plows, or agricultural discs (Butt 1988).

Mounding machines scoop up a quantity of organic and mineral soil and invert it, leaving a mineral soil cap resting on a layer of inverted humus (Butt 1988). Mineral-capped, inverted humus mounds can provide very favourable planting spots, although some variability in seedling performance has been noted.[19] At the FRDA 1.01 site in the SBSj1 subzone, seedlings in mounded areas were outperforming seedlings in the control and disc areas 4 years after treatment (D. Draper, pers. comm., Sept. 1990). At the Upper Coal Mine Road site (FRDA 1.16) in the Wet Cool ESSF (ESSFwk) subzone, seedlings growing on inverted humus mounds with 14 cm or more of mineral capping were superior to those produced by other treatments for all seedling growth parameters that were measured. Six years after planting, most leaders had good growth and the trees were essentially free to grow.[20]

On many sites, mounding results in reduced vegetation competition around the seedlings for several years. At the FRDA 1.01 site, vegetation control by mounding is still noticeable 4 years after treatment. At the Upper Coal Mine Road site (FRDA 1.16), most seedlings on mounds with 14-cm caps are still, 7 years after treatment, surrounded by bare mineral soil with little competing vegetation.

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12 Herring and Letchford, 1987.
13 Taylor *et al.*, 1990.
14 Sutherland, 1990b.
15 Herring and Letchford, 1987.
16 Ibid.
17 Taylor *et al.*, 1990.
18 McMinn, R. 1990b. Archie Road (South) demonstration plot. Unpubl. tour guide.
19 McMinn, R. 1990c. FRDA 1.16 Synopsis of achievements and findings. Presentation to NITAC, Jan. 1990.
20 McMinn, R. 1990d. Upper Coal Mine Road demonstration plot. Unpubl. tour guide.

Where the competing vegetation is tall or very aggressive, however, mounding may not be an effective means of vegetation control (R. McMinn, pers. comm.). At the FRDA 1.17 site, over half the mounds were infiltrated with fireweed rhizomes and other fibrous roots. The mounds also appeared to be a good seedbed for fireweed. During the second growing season after treatment, fireweed cover in the mounded area had increased above pretreatment levels.[21]

At the FRDA 1.17 site, damage to seedlings from snowshoe hares was lower in the mounded areas than in other treatment areas, except brown-and-burn. Control of hare damage by mounding has also been observed on other sites (L. Bedford, pers. comm., March 1991).

Mounding differs from most other site preparation methods in that the vegetation disturbance is limited to a small area around each planting site. Use of this method may reduce the need for later herbicide treatments. Where it is desirable to maintain wildlife habitat or other resource values by minimizing the impact of site preparation on the overall vegetation community, mounding may therefore be a good option.

2.2.4 Mixing

Soil mixing brings together organic and mineral material so that seedlings have access to nutrients. Ideally, mixing should fragment the roots and rhizomes of competing vegetation, loosen the soil, and result in a warmer soil surface during the growing season (Butt 1988). Fast (high rpm) mixing implements effectively comminute roots and rhizomes, thus stimulating herbs and grasses. Slow mixing may stimulate suckering (L. Bedford, pers. comm., March 1991).

At the Archie Road North and South sites (FRDA 1.16), 14–15 years after planting, conifers planted in mixed soil strips greatly outperformed conifers in scalped strips. Hardwoods had invaded both treatment areas, although they tended to be slightly less frequent in the mixed soil strips.[22] At these sites, soil mixing resulted in both satisfactory conifer performance and browse availability for wildlife.

2.3 Chemical Treatments

Unlike fire or mechanical site preparation, chemical treatment affects the vegetation without directly affecting other ecosystem components, such as soil or woody debris. The application of herbicides to vegetation dramatically affects the biomass, structure, and species composition of the vegetation, and may therefore affect wildlife. This section summarizes the information provided by FRDA northern Interior projects about those effects.

2.3.1 Effects on vegetation structure

When applied at operational levels (≤ 2.1 kg a.i./ha), glyphosate can reduce overall vegetation abundance greatly. At a backlog hardwood site in the BWBS zone (FRDA 1.02), for example, glyphosate had reduced both cover and height of the overall vegetation by about 70% 1 year after application.[23] The effect, however, may be short-lived. In ESSF brushfields (FRDA 1.17), total cover of major vegetation species decreased from 55 to 10% 1 year after treatment with glyphosate, but increased to 44% total cover by the 2nd year.[24] Herb-dominated communities in the SBS zone (FRDA 1.34) were significantly reduced by glyphosate 1 year after application, but returned to near pretreatment levels 2 years later (Fig. 3).[25] In contrast, a shrub-dominated community in that study was still much reduced 2 years after treatment.

The impact of aerially applied herbicide on vegetation strata often depends on the initial structure of the vegetation. At the FRDA 1.34 sites, the herb layers were most severely affected where no shrub layer was present to intercept the herbicide (Fig. 3). At the FRDA 1.02 site, foliage interception by *Populus* spp. apparently reduced the impact of glyphosate on reedgrass and prickly rose.

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[21] Sutherland, 1990a, 1990b.
[22] McMinn, 1990a, 1990b.
[23] Herring and Letchford, 1987.
[24] Sutherland, 1990a.
[25] Sullivan, 1990a.

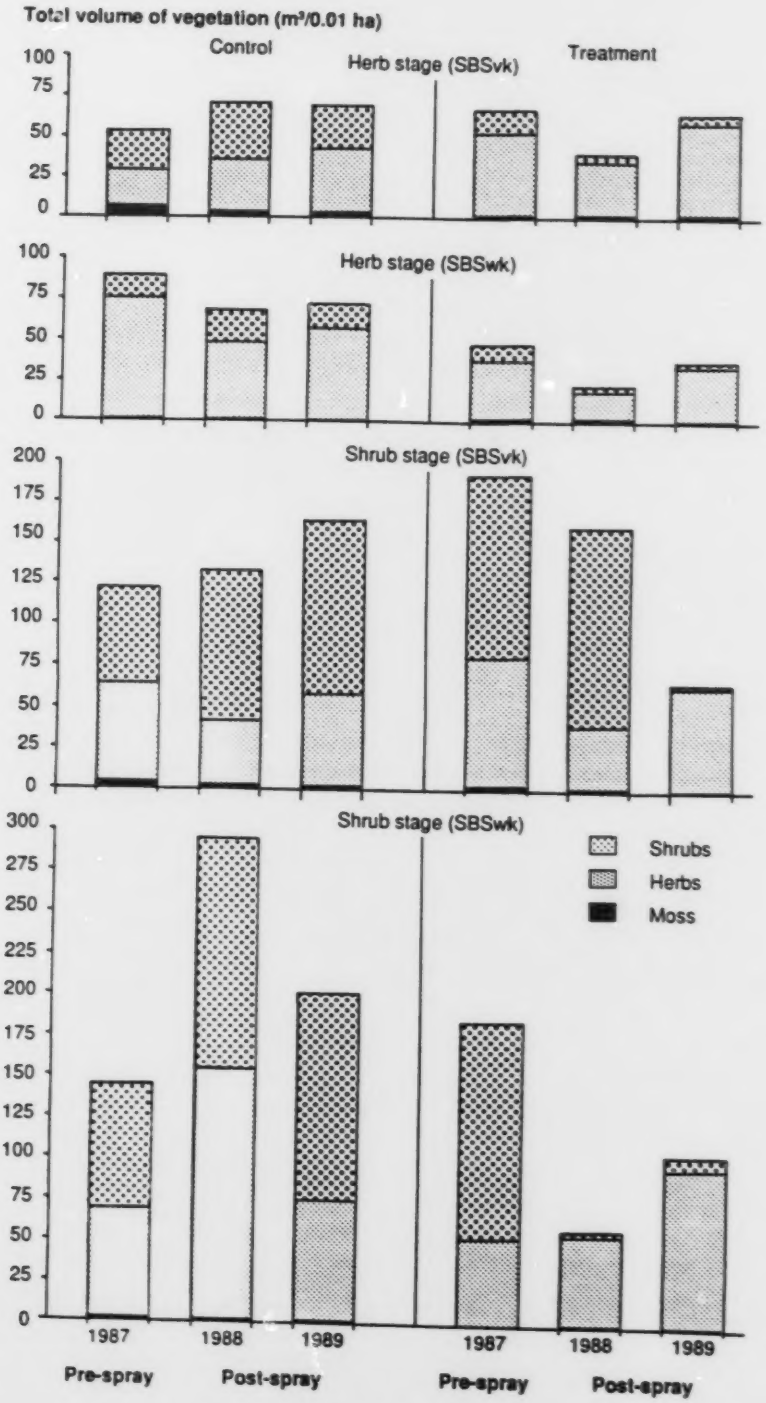


FIGURE 3. Response of vegetation volume (m^3/0.01 ha) to glyphosate herbicide in herb and shrub stages, sub-boreal spruce forest (Sullivan 1990a:Fig. 1). Herbicide was applied in 1988 at shrub stage (SBSvk) site and in 1987 at the other treatment sites.

Because aerially applied herbicide tends to have greater and more lasting effects on the taller than the lower vegetation, birds, browsing mammals, and mammals that use tall vegetation for cover may be most affected.

2.3.2 Effects on individual plant species

Assessments of the vegetation as a whole, or of individual layers, sometimes mask major changes in species composition. Herb layers at the FRDA 1.34 sites, though not much different in overall abundance 2 years after treatment with glyphosate, had changed markedly in species composition (Figs. 4 and 5).

Changes in the abundance of particular species are not always in the same direction, however, especially more than 1 year after treatment. Fireweed decreased in abundance at two of the FRDA 1.34 treatment sites, for example, and increased in abundance at the other two. Furthermore, changes in species composition are a result of many factors other than just differing species sensitivities to the herbicide. One factor, for instance, is differing abilities of species to aggressively occupy spaces left by the species most affected by the herbicide.

Different wildlife species respond differently to changes in vegetation structure and species composition. For example, at the FRDA 1.34 site, the shrub layer initially included a number of forage species for moose, such as willows, black twinberry (*Lonicera involucrata*), black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), and red-osier dogwood (*Cornus sericea*). The extreme reduction in the shrub layer after herbicide treatment (Fig. 3) likely made the sites unattractive to moose. However, at the two sites where fireweed was reduced by herbicide treatments, the abundance of important forage species for bears increased — horsetails (*Equisetum* spp.) at the SBSwk herb stage site (Fig. 4) and cow-parsnip (*Heracleum sphondylium*) at the SBSvk shrub stage site (B. McLellan, pers. comm.) (Fig. 5).

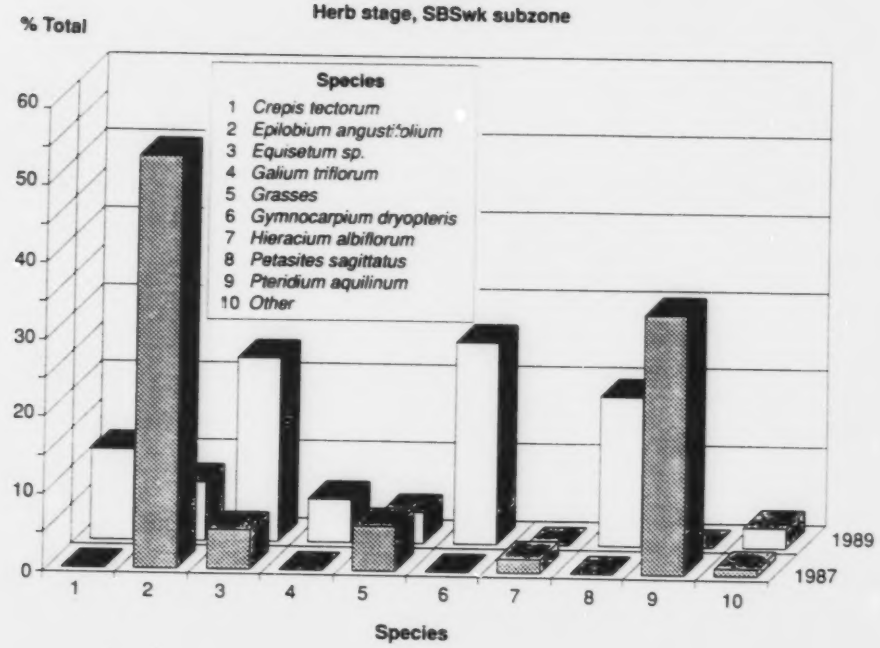
Several other projects have provided information about the responses of some wildlife forage species to glyphosate. These results, summarized in Table 2, must be interpreted cautiously as they are affected by many variables, including structure and species composition of the surrounding vegetation, variations in actual herbicide dosage, and microsite characteristics.

Effects on individual species reported in these studies were generally consistent with those reported in the literature. Impact on vegetation at the FRDA 1.46 (Caine Creek) site was less than at the other sites; even susceptible species such as birch and trembling aspen were affected less than expected. Red-osier dogwood, which is considered to be fairly resistant, was eliminated at the FRDA 1.34 site. It is not clear why that occurred, but because its initial abundance was fairly low (absolute volume 3.35 m^3/0.01 ha), the results may have been a product of small sample size.

Two NITAC projects have reported findings that will help researchers determine responses of willows to herbicide treatment. Haeussler and Coates (1986:138) wrote:

> Herbicide response in willows is difficult to monitor because of the difficulty of identifying willow species. Because of the great variability both between and within species, herbicide response can vary dramatically. . . .

Through FRDA 1.19, Porter (1989) produced a manual that will assist researchers in identifying the willow species in treatment areas in the SBS zone. The manual also provides information about the autecology, distribution, phenology, and browse utilization of the species. In that study, moose appeared to select willow species mainly on the basis of availability, although other factors may also have been operating. Preferences and browsing intensity varied among subzones. Overall, five species (*Salix bebbiana*, *S. discolor*, *S. lucida* ssp. *lasiandra*, *S. scouleriana*, and *S. sitchensis*) provided 80–90% of the forage.



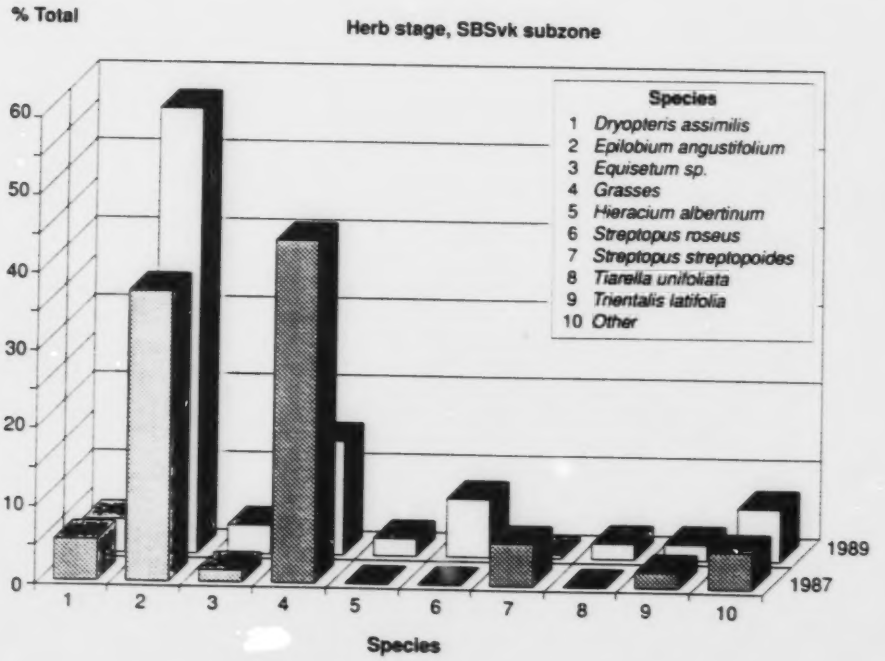
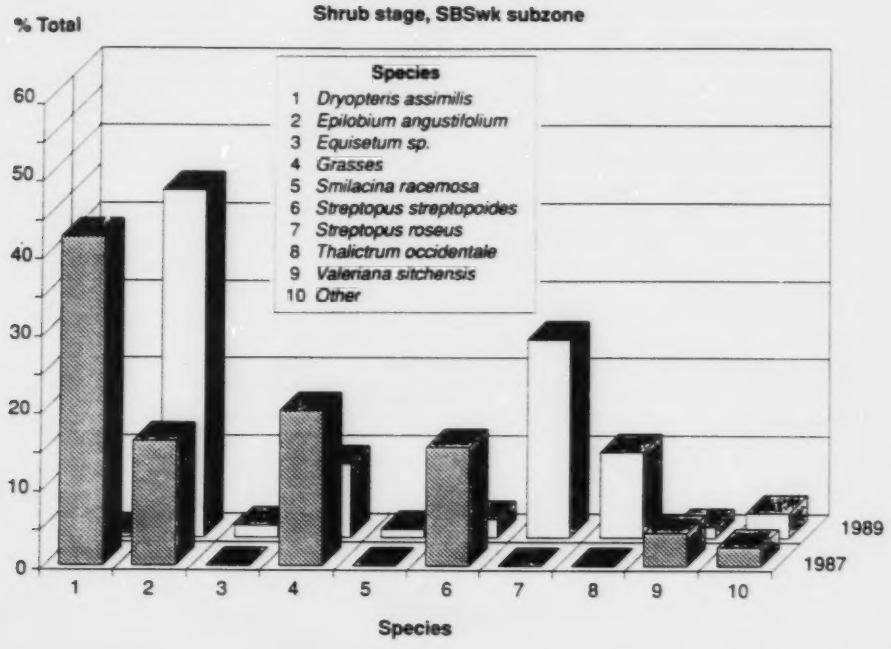


FIGURE 4. Response of species in the herb layer (percentage of total volume [m^3/0.01 ha]) to glyphosate herbicide in herb stage communities, sub-boreal spruce forest (from Sullivan 1990a). Herbicide was applied in 1987.



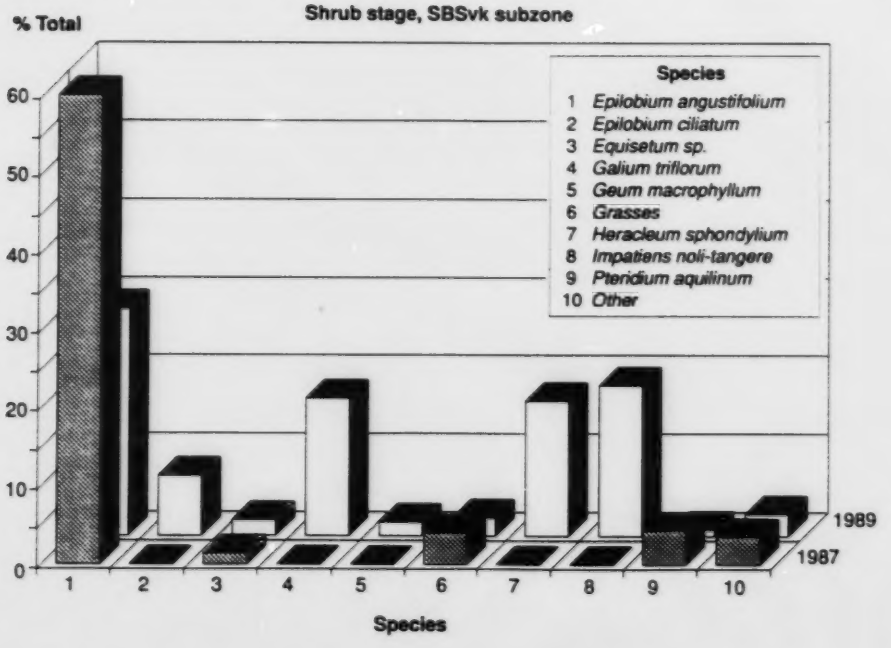


FIGURE 5. Response of species in the herb layer (percentage of total volume [m^3/0.01 ha]) to glyphosate herbicide in shrub stage communities, sub-boreal spruce forest (from Sullivan 1990a). Herbicide was applied in 1987 at the SBSwk site and in 1988 at the SBSvk site.

Bancroft and Butt[26] (FRDA 1.33) investigated the susceptibility of different willow species to glyphosate, and the effects of different rates and timing of glyphosate treatments on willows. The results did not indicate any differences in susceptibility among the four species tested (*S. bebbiana*, *S. discolor*, *S. lucida*, and *S. sitchensis*), but the differences within species were great. Within a single treatment, some individuals were apparently unaffected while others were killed. The authors caution that time and area replications are needed before the results are generalized. It is apparent, however, that species differences alone do not account for the response variability that has been noted in willow.

Different rates and timings of application also produced significantly different results. The maximum rate of glyphosate approved for operational use is 2.1 kg a.i./ha, but higher rates may be approved for research trials. Glyphosate applied at 1 kg a.i./ha had little or no effect on willow vigour, regardless of application date. Willows were similarly unaffected by glyphosate applied on September 7 (after the formation of the abscission layer). Significant reductions in growth and vigour followed applications of 2–3 kg a.i./ha of glyphosate in early July and late August. The most severe damage resulted from 3 kg a.i./ha applied on July 6.

The implications of the herbicide treatment on browse availability over time are unclear, and complicated by response variability within treatments. One year after treatment, affected willows had shorter leaders, fewer live stems, fewer side stems, and thus less available browse than did those of the controls. Studies by Lloyd[27] indicate that some of the treated plants are likely to die or remain in poor condition, while others are likely to produce more browse than before. Glyphosate affects willow by altering the normal pattern of growth so that lower nodes are activated and new shoots produced. In treated plants, the most vigorous new growth often arises from the lower part of the stem.[28] That change in plant architecture may benefit moose, especially where much of the willow has grown beyond the reach of the animals. The increased production of available browse observed in some willow plants may occasionally mitigate the effects of glyphosate application on moose habitat. However, the variability of the responses of willows is so great that glyphosate is unlikely to be effective as a habitat enhancement tool for overgrown winter ranges.

Small mammal damage and intensity of browsing on willow were also measured at the FRDA 1.33 sites, because those factors may interact with herbicide effects. Almost no small mammal damage occurred, and browsing intensity was significantly lower during the year following treatment than in the year before, on both treatment and control plots. There was no correlation between the number of browsed stems and any treatment, timing, or combination of the two.

The absence of significant differences in browsing intensity between treatment and control plots does not imply that utilization is unaffected by herbicide treatments. The experimental layout (a grid of variously treated 4 × 5 m plots) was not designed to assess ungulate use; from the standpoint of a moose, the entire area may seem to be treated.

Lloyd[29] found that degree of damage significantly affected browsing by moose, 1.5 and 2.5 years after glyphosate application. Moose preferred untreated areas to treated areas and lightly damaged stems to moderately damaged stems. They did not browse on severely affected vegetation.

Additional information on the effects of herbicides on willows and other browse species for moose has been summarized in FRDA Memo No. 161 (Lloyd 1990).

2.3.3 Responses of wildlife

Few FRDA northern Interior studies directly addressed the responses of wildlife to herbicide treatments.

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[26] Bancroft and Butt, 1990.

[27] Lloyd, R.A. 1989. Assessing the impact of glyphosate and liquid hexazinone on moose browse species in the Skeena Region: third-year report. Unpubl. report prepared for B.C. Min. Environ., Smithers, B.C.

[28] Ibid.

TABLE 2. Effects of glyphosate on forage species used by wildlife, as reported in FRDA northern Interior projects

Forage species	Wildlife species[a]	Effects of glyphosate[b]	Comparison with literature
Betula papyrifera Paper birch	Moose, mule deer, elk, beaver, small mammals, birds	Initial volume reduced to 46% (FRDA 1.46).	Glyphosate "highly effective at rates ≥ 2.24 kg a.i./ha."[c] Birch usually killed or severely damaged.[d]
Cornus sericea Red-osier dogwood	Moose, mule deer, white-tailed deer, elk, black bear, grizzly bear, beaver, snowshoe hare, many birds	Initial volume reduced to 0 (FRDA 1.34).	Quite tolerant of glyphosate.[c] Fairly resistant; slightly to severely damaged.[d]
Epilobium angustifolium Fireweed	Moose, deer, bears	Cover reduced from 8 to 1% (FRDA 1.02). Cover reduced from 16 to 3% 2 years after treatment (FRDA 1.17). See text for discussion of variable response in FRDA 1.34 (Figs. 2–3).	Reduces height and cover for 1–2 years but may not kill fireweed.[e]
Lathyrus nevadensis Purple peavine	Bears, elk, mule deer[f]	Cover 12% of control; height 31% of control 1 year after treatment (FRDA 1.27).	No information.
Lonicera involucrata Black twinberry	Bears, moose, birds	All plants killed (FRDA 1.02). Initial volume reduced to 0–9% (FRDA 1.34).	Severe to very severe damage.[g] Very susceptible; usually killed.[d]
Populus balsamifera Poplar	Moose, white-tailed deer, mountain goat, bighorn sheep, beaver, snowshoe hare, small mammals, black bear (dens)	All plants killed (FRDA 1.02). Initial volume reduced to <1% (FRDA 1.34).	Inconsistent results. "Good to excellent control."[h] Low to severe damage.[i] Susceptible; usually killed or severely damaged.[d]
Populus tremuloides Trembling aspen	Moose, mule deer, beaver, porcupine, snowshoe hare, small mammals, ruffed grouse	44 of 47 plants killed (FRDA 1.02). Initial volume reduced to 28% (FRDA 1.46).	"Good to excellent control."[h] Severe damage at 2.0 kg a.i./ha; low damage at 1.5 kg a.i./ha.[i] Susceptible; usually killed or severely damaged.[d]
Rosa acicularis Prickly rose	Bears, mule deer, white-tailed deer, birds, small mammals	38 of 45 plants killed (FRDA 1.02). Cover 12% of control; height 38% of control (FRDA 1.27).	Moderate to severe damage.[h] Fairly resistant; slightly to severely damaged.[d]
Rubus parviflorus Thimbleberry	Bears, birds, small mammals, moose	Cover 4% of control; height 20% of control (FRDA 1.27). Initial volume reduced to 3–4% (FRDA 1.34) and 17% (FRDA 1.46).	Moderately sensitive but usually resprouts.[h] Fairly resistant; slightly to severely damaged.[d]
Salix spp. Willows	Moose, mule deer, white-tailed deer, mountain goat, elk, beaver, small mammals, birds	Variable results; 65–100% efficacy (FRDA 1.02). Original volume reduced to 4% (FRDA 1.34) and 59% (FRDA 1.46). See text for discussion of FRDA 1.33.	Variable. Damage ranges from 0 to 100%.[d,g] See text.

TABLE 2. (Continued)

Forage species	Wildlife species[a]	Effects of glyphosate[b]	Comparison with literature
Sambucus racemosa Red elderberry	Moose, deer, elk, porcupine, small mammals, birds	Initial volume reduced to 0–12% (FRDA 1.34).	Variable. Most studies report very severe damage, but a few report light damage and rapid re-sprouting.[g]
Viburnum edule Highbush cranberry	Moose, deer, mountain goat, bighorn sheep, snowshoe hare, beaver, bears, small mammals, birds	26 of 43 plants killed, the rest severely injured (FRDA 1.02).	Moderate to severe damage.[g] Susceptible; usually killed or severely damaged.[d]

[a] Haeussler and Coates 1986; Balfour 1989; D. Hatler, pers. comm., Jan. 1991; D. King, pers. comm., Jan. 1991; B McLellan, pers. comm., March 1991.
[b] All results 1 or 2 years after mid- to late summer treatment with < 2.2 kg a.i./ha glyphosate applied as foliar spray. Results based on very low initial abundance are excluded.
[c] Comeau *et al.* 1989.
[d] Lloyd 1988.
[e] Haeussler and Coates 1986; Comeau *et al.* 1989.
[f] *L. nevadensis* known to be browsed by wildlife; use of *L. ochroleucus* by grizzly bear and mule deer has been reported.
[g] Haeussler and Coates 1986; Balfour 1989.
[h] Haeussler and Coates 1986.
[i] Balfour 1989.

FRDA 1.34 investigated the effect of herbicide use on small mammal populations on shrub- and herb-dominated sites in two subzones of the SBS.[30] Southern red-backed vole, meadow vole (*Microtus pennsylvanicus*), and deer mouse numbers were much reduced 1 year after treatment on both treatment and control blocks. It is unclear whether those results were due entirely to natural fluctuations in the populations, or to other factors as well. At least some of the control areas were completely surrounded by treated areas (M. Spike, pers. comm., Jan. 1991). If control areas are habitat islands, populations may be affected by altered patterns of immigration and emigration, even if the vegetation in the control area is unaffected.

Aside from that general pattern, changes in small mammal populations tended to be associated with changes in the herbaceous vegetation. No clear pattern of small mammal response was evident in the shrub-dominated communities, presumably because the herb layer was affected little by the herbicide. In the herb-dominated communities, there appeared to be at least partial recovery of small mammal populations in the 2nd year after treatment, although population fluctuations in the control area make the results difficult to interpret.

The mechanisms by which herbicide treatments affected small mammals were not investigated in FRDA 1.34, but potential mechanisms were discussed. The deer mouse is a generalist species, and is not usually negatively affected by herbicide treatments. The author suggested that, in this study, the loss of moist microclimates and associated food resources may have contributed to the reduction in numbers. Loss of cover, as well as food, may have affected southern red-backed vole populations.

Effects of various overstory and understory treatments on browse levels are being studied in an SBS zone aspen stand (FRDA 1.27). One year after glyphosate treatment of the understory only, no sign of browsing was found. Where the site had been bladed and then treated with glyphosate, however, a proliferation of the herb layer had occurred. Several herb species (*Arnica cordifolia*, *Fragaria virginiana*, and *Viola canadensis*) had been heavily browsed, and prickly rose and thimbleberry had been lightly browsed.

2.3.4 Downslope movement of hexazinone

Most studies of chemical treatment have employed glyphosate, the herbicide that is used most often in British Columbia forestry operations. However, FRDA 1.21 (Beaudry 1990) addressed environmental concerns about liquid hexazinone, another herbicide that is approved for operational forestry use.

Hexazinone is highly water soluble and mobile in soil. Although it was designed to move only a few metres from its spot of application, several cases of much greater movement (up to 150 m) have been documented in the Prince Rupert Forest Region. Concerns were expressed there over potential damage by uncontrolled movement of the herbicide to streamside vegetation in a pesticide-free zone, or to browse species in wildlife habitat. Contamination of fish-bearing streams was of lesser concern because of the relatively low toxicity of hexazinone (LC_{50} trout of about 875 ppm).

Through FRDA 1.21, trials were initiated at two sites with different soil characteristics to investigate the extent and processes of the downslope movement of hexazinone. Both sites were on slopes of about 15%. Surface and sub-surface soil water was sampled from specially designed troughs located at intervals downslope of the application area. Hexazinone-sensitive plants were also used to assess the extent of downslope movement.

Hexazinone residues in water samples ranged from undetectable to 0.39 ppm, but were generally low; 82% of all samples analyzed contained less than 0.05 ppm. Migration of detectable hexazinone in soil water reached at least 25 m downslope in all treatment combinations. Most of the damage to susceptible plants occurred within 5 m downslope of the treatment area, but in several cases damaged plants were observed up to 60 m downslope. The damaged plants were always in a narrow strip less than 2–3 m wide, along preferential pathways of downslope water movement.

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[29] Lloyd, 1989.
[30] Sullivan, 1990a.

Most of the downslope movement was sub-surface rather than over the soil surface, and occurred during the first fall and spring after application. Hexazinone in the soil water was almost undetectable 12 months after treatment.

To minimize the downslope movement of hexazinone, the author recommended treating in early spring rather than in fall, avoiding sites where mechanical equipment has created long continuous ruts, and limiting the use of hexazinone to drier interior ecosystems and to sites where a continuous layer of at least 2–3 cm of organic matter is present.

Because of the narrow strips affected and the low concentrations found, regulatory agencies agreed that hexazinone, as applied in the FRDA 1.21 trial, had little potential to cause significant adverse effects on the environment. Movement may be greater on sites with steeper slopes, less organic matter, or wetter conditions.

2.4 Planting Stock

Selection of large stock types enhances conifer performance and, on some sites, may make site preparation unnecessary.[31] At the Upper Coal Mine Road site (FRDA 1.16), large stock (Sx 1+0 PSB-313) without site preparation was less cost-effective than standard stock (Sx 2+0 bareroot) with +14 cm capped humus mounds, but more cost-effective than standard stock with blade scarification, patch scarification, or no site preparation.[32] At the Lower Coal Mine Road site, standard 2+1 bareroot stock in an untreated area was generally suppressed by vegetation 6 years after planting, but large 2+1 bareroot stock was nearly free to grow.[33] Fifteen years after planting, larger stock types outperformed smaller stock types at the Archie Road North site. The differences were greater in spruce than in pine, and in untreated than in scalped areas.[34] Where wildlife concerns or other resource values make site preparation undesirable, the use of large stock may be an effective option.

Selection of large planting stock may also reduce the probability of damage to plantations by small mammals (Sullivan 1990).

2.5 Introduction of Nitrogen-Fixing Species

Nitrogen-fixing organisms may be used to enhance soil fertility and supply crop trees with a form of long-term, slow-release nitrogen (Trowbridge 1990). The introduction of a nitrogen-fixing species, alsike clover (*Trifolium hybridum*), at the FRDA 1.13/1.48 site significantly reduced the cover of some native plants (reedgrass, prickly rose, and birch-leaved spirea [*Spiraea betulifolia*]) (Trowbridge 1990), and appeared to attract voles. The clover patches were the only locations in the study area where damage to seedlings by voles was observed during FRDA 1.49 studies. The damage did not appear to result from feeding, but from clipping of seedlings that were located along runways (D. Hatler, pers. comm., Jan. 1991).

The use of clover as an alternative food to reduce feeding on seedlings by voles will be investigated in FRDA 1.42. The success of such an approach depends on the assumptions that voles prefer clover to seedlings and that increased food abundance will not result in increased vole numbers.[35] The observations of Hatler suggest that the clover should be planted some distance from the seedlings.

2.6 Conifer Release Cuts

The potential of conifer release cuts to rehabilitate IU backlog was studied in FRDA 1.01A. A release cut was carried out to eliminate trembling aspen and poor quality or crowded conifers on a site in the SBSwk subzone, adjacent to the FRDA 1.01 study area (R. McMinn, pers. comm., Sept. 1990). Unfortunately, individual treatment areas were too small (0.5 ha) for assessments of direct impacts on wildlife.

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[31] McMinn, 1990c.
[32] McMinn, 1990d.
[33] McMinn, R. 1990e. Lower Coal Mine Road demonstration plot. Unpubl. tour guide.
[34] McMinn, 1990a.
[35] Sullivan, T.P. 1990b. Population dynamics of voles and lemmings and control of damage in the Prince Rupert Region: progress report 1989–1990. Mammal Pest Management Ltd., Langley, B.C. Unpubl. report.

Many areas that were logged to IU standards in the 1950's and 1960's are superior wildlife habitat today. The partial removal of the canopy stimulated understory productivity, resulting in stands that are rich in forage and cover species and in structural diversity. The untreated stands adjacent to the treatment areas at the FRDA 1.01 and 1.20 sites are examples of IU stands that are good wildlife habitat and have conifers that appear to be growing well.

Until recently, IU stands supporting fewer than 700 stems per hectare of acceptable species (excluding subalpine fir) were considered NSR (Butt 1988). However, those stocking standards were developed for young even-aged stands and are not appropriate for older or uneven-aged stands. Staff in the Prince George Forest District are currently reassessing stands previously classified as NSR, taking into consideration such factors as the growth rate of the crop trees, the stocking level, and non-timber resource values. The use of modified standards for classifying NSR may result in more release cutting, and in more stands being classified as satisfactorily stocked (R. Richards, pers. comm., Feb. 1991).

Future FRDA projects should give more attention to release cutting and its impact on wildlife habitat values. By eliminating the deciduous component and snags, release cutting has the potential to reduce the habitat value of the stand. Research is needed to develop prescriptions that will maintain habitat values as much as possible.

3 CONTROL OF DAMAGE CAUSED BY WILDLIFE

Two projects have focussed on development of methods to control damage to plantations by wildlife. In FRDA 1.42, the population levels and cyclic phases of meadow vole and lemming populations in burned and unburned plantations are being investigated, and the effectiveness of herbicide treatment, alternative foods, and weasel odour repellents in reducing populations and damage to seedlings is being tested.[36] Another study, FRDA 1.46, assesses the influence of herbicide treatment on snowshoe hare populations and damage to coniferous trees by hares, and field tests encapsulated repellents (predator odours and anti-feedant compounds) for efficacy and durability in plantations.[37]

A future approach might be to investigate the effects of maintaining habitat elements, such as coarse woody debris and snags, that favour predators.

4 MONITORING EFFECTS ON WILDLIFE AND WILDLIFE HABITAT

Initially, FRDA northern Interior projects were designed to identify the effects of silvicultural treatments on plantation performance only, and not on wildlife habitat. Recognition of that problem later led to the development of methods for monitoring the structure and composition of habitat, and the occurrence of wildlife.

Stevenson and Hatler (1989) recommended that standard vegetation measures be used in all new FRDA silvicultural research projects in which treatment effects on wildlife habitat are a concern. The recommended assessments, based on the environmental monitoring procedures developed by the provincial government (Habitat Monitoring Committee 1990), also include a simple soil assessment to identify potential fisheries impacts. All researchers should take into consideration the requirements for vegetation assessments when they plan the size and layout of treatment areas.

Many inferences about wildlife habitat can be made from information on the structure and composition of the vegetation, but detailed vegetation assessments do not address all the concerns of wildlife biologists. Biologists do not have enough information about the habitat relationships of most wildlife species to make

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[36] Sullivan, 1990b.

[37] Sullivan, T.P. 1990c. Use of habitat alteration and encapsulated biological repellents to protect coniferous plantations from snowshoe hares: progress report 1989–1990. Applied Mammal Research Institute, Langley, B.C. Unpubl. report.

adequate inferences from vegetation data. Silvicultural practices may affect wildlife by means other than their effects on vegetation structure and composition. There is a need for silvicultural treatment monitoring that incorporates measures of wildlife presence and use (Stevenson and Hatler 1989).

In response to that need, a background document explaining the rationale and development of the wildlife monitoring method,[38] a field manual,[39] and a short training video have been prepared (FRDA 1.49). The method is designed to be compatible with the environmental monitoring procedures of the Habitat Monitoring Committee (1990). It is intended for use at experimental installations with large treatment areas, and at operational treatment sites. The method involves having an investigator walk along a pre-selected line, recording direct contacts with wildlife and indirect evidence of wildlife occurrence. Accumulated wildlife monitoring data will provide insights on relationships between vegetation and wildlife, as well as on impacts of silvicultural treatments.

5 RECOMMENDATIONS

5.1 Additional Monitoring of FRDA Northern Interior Projects

Most of the field projects discussed in Sections 2 and 3 were established within the last 4 years, and the results cover only the first year or two after silvicultural treatment. Impacts of treatments on wildlife and wildlife habitat generally last much longer. Whether any projects warrant continued or additional monitoring was also considered in this review.

Continued monitoring of many of the projects discussed in Sections 2 and 3 is already planned (FRDA 1.01/1.01A, 1.02, 1.13, 1.17, 1.20, 1.27, 1.42, 1.46). Most were designed to investigate the effects of treatments on plantation development. The potential to make interpretations about wildlife habitat from silviculture projects is generally limited by study design, size of treatment area, and the response variables measured. Nevertheless, the results will allow wildlife interpretations like those in Sections 2 and 3 to be extended through time.

To anticipate how treatments will affect wildlife, and to plan treatment schedules, managers need to know the duration as well as the nature of the treatment effects on habitat. In general, investigations of these matters should be continued until the response variables return to pretreatment levels, or until it is evident that they will not do so. Monitoring of willows at the FRDA 1.33 (Rus) site should be carried on at 2-year intervals. Continued monitoring at the FRDA 1.34 site does not seem warranted, since small mammal populations (except meadow voles) appeared to be near pretreatment levels in the 2nd year after treatment.

Additional monitoring is recommended only at the FRDA 1.13/1.48/1.49 site. Although wildlife transects carried out as part of FRDA 1.49 were intended primarily for developing monitoring methodology, they provided information on the relative occurrence of various wildlife species in the treated and untreated areas, 3 years after burning. Continued wildlife monitoring would provide information on the pattern of species occurrence associated with post-fire succession. Wildlife monitoring should be carried out in conjunction with Level 2 vegetation assessments. Assessments of site nutrient status and seedling performance at 5-year intervals are already planned (R. Trowbridge, pers. comm., March 1990).

The FRDA 1.13/1.48/1.49 area also offers researchers the opportunity to monitor the wildlife effects of an alternative rehabilitation treatment: thinning of dense lodgepole pine stands. While thinning is not generally a viable silvicultural option in many overstocked pine stands, it may be considered in stands that are young or only moderately dense (Butt 1988; Blackwell *et al.*[40]). Immediately adjacent to the FRDA treatment area are lodgepole pine stands that were thinned from 6000–8000 stems per hectare to 1400–1600 stems per hectare and fertilized in 1985.[41] Comparable unthinned stands and patches of old growth are also present

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[38] Hatler, D.F. In prep. Development of a method for monitoring wildlife in managed forests. B.C. Min. For., Victoria, B.C.

[39] Hatler, D.F. In prep. A method for monitoring wildlife in managed forests: a field manual (first approximation). B.C. Min. For., Victoria, B.C.

[40] Blackwell *et al.*, 1989.

[41] Yole, D., R. Carter, and R. Trowbridge. 1990. Evaluation of five single tree fertilizer trials in thinned lodgepole pine stands in the Prince Rupert Forest Region. B.C. Min. For., Smithers, B.C. Unpubl. report.

(F. Milinazzo, pers. comm., Oct. 1990). Extension of the monitoring to the thinned areas would provide information for use in treatment decisions about stands where either thinning or knockdown-and-burn are options.

5.2 Demonstration Areas

Some field installations have value as demonstration areas for managers concerned with the effects of silvicultural treatments on wildlife habitat. Demonstration potential depends on the degree to which interesting biological responses to treatment are visible; on the accessibility of the site; and on the ease with which the layout can be understood by visitors. Assessments of the field sites having demonstration potential are summarized in Table 3.

TABLE 3. Summary of FRDA northern Interior installations with demonstration value for wildlife habitat

Project	Demonstration features	Access	Laid out for demonstration?
1.01/1.01A	Conspicuous vegetation differences between herbicide, mounding, disc and control treatments. Adjacent conifer release trial and control area.	Good. On main forest road < 1 hour from Prince George.	Yes
1.02	Not seen. Vegetation differences among treatments are evident. Site is near several other field installations which could be viewed in a one-day field trip.[a]	Good. Between Dawson Creek and Chetwynd.	Yes
1.13/1.48/1.49	Vegetation differences among burn types are subtle. Not recommended as wildlife demonstration area unless wildlife monitoring is extended to thinned pine stands and results warrant demonstration use.	Poor. About 75 minutes from Houston. Difficult to find.	Yes
1.16 Upper Coal Mine Road	Mounding with various capping depths; patch scarification; blade scarification. Treated in 1983. Local vegetation control on mounds is conspicuous. Silviculture tour guide has been prepared.	Medium. About 1 hour from Prince George.	Yes
1.16 Lower Coal Mine Road	Mounding with various capping depths; patch scarification; blade scarification. Treated in 1983. Stock type differences are conspicuous. Silviculture tour guide has been prepared.	Medium. About 1 hour from Prince George.	Yes
1.16 Archie Road South	Scalping; early season mixing; late season mixing. Treated in 1973. Relationship between degree of soil disturbance and later colonization by hardwoods. Silviculture tour guide has been prepared.	Medium. About 75 minutes from Prince George.	Yes
1.16 Archie Road North	Various stock types; scalping, mixing, clipping. Treated in 1971 and 1972. Soil disturbance/ hardwood relationship; conspicuous stock type differences; vegetation suppression by clipping. Silviculture tour guide has been prepared.	Medium. About 75 minutes from Prince George.	Yes. Confusing layout; needs site map.
1.17	Not seen. Herbicide, spray-and-burn, mounding, screefing. Vegetation differences among treatments may not be long-lasting.	Good. About 45 minutes from Hwy 97 turnoff near Quesnel.	Yes

TABLE 3. (Continued)

Project	Demonstration features	Access	Laid out for demonstration?
1.18	Treatments (scarification, annual herbicide application, fertilization, mulch) are not typical of operational practices. An excellent introduction to the problem for wildlife biologists because of the dramatic relationship between intensity of treatment, seedling performance, and suppression of wildlife habitat elements (competing vegetation, debris).	Good. On main forest road 1 hour from Prince George.	Yes
1.20	Windrow-and-burn, broadcast burn, spray-and-burn, disc-trenching. Treated in 1987. Additional herbicide treatment in 1990. Vegetation differences among treatments still conspicuous in 1990. Compare untreated stand of IU logging east of the weather station.	Medium. About 95 minutes from Prince George.	Yes
1.33 Rus site	Some rate and timing combinations produced noticeably different effects on willow. Some response differences within treatments are striking. Manual severing increased sprouting greatly.	Poor. About 70 minutes from Prince George. Difficult to find.	No. Confusing layout; needs tour guide.
1.42, 1.46	Not seen. Both studies have demonstration potential, depending on results.[b]	Not assessed.	No

[a] L. Herring, pers. comm., Feb. 1991.
[b] T. Sullivan, pers. comm., Feb. 1991.

Some demonstration field sites are close enough together that they could be used in a group field tour. For example, the FRDA 1.18 site, the two Archie Road sites (FRDA 1.16), and either FRDA 1.01/1.01A or the Coal Mine Road sites could be visited in a day trip from Prince George. The FRDA 1.02 site and nearby installations could be combined in a field tour from Dawson Creek. Sites for FRDA 1.17 and 1.20 could be visited in a day trip from Quesnel.

5.3 Planning New Projects

Many FRDA projects have limited relevance to wildlife because they were not designed to evaluate treatment effects on wildlife habitat. If a second FRDA program were established, some projects should be designed to assess treatment effects on wildlife as well as on silviculture. The following points should be considered:

- Level 2 vegetation assessments or the equivalent, as described by Stevenson and Hatler (1989), should be the minimum level of vegetation description.
- Wildlife assessments require treatment and control areas that are larger than the areas required for silvicultural assessments. Small research blocks might affect wildlife differently than would operational blocks; monitoring should be done in both. When research blocks are used, the investigator has more control over the study design and layout and can relate wildlife data to other experimental results. However, the number of research blocks that are large enough for wildlife monitoring is likely to be limited. Monitoring of operational blocks in a variety of subzones and sites should be used to increase the data base on wildlife response to treatments. Some large, uniform study areas should also be sought so that the effects of block size on wildlife can be investigated.

- The need for pretreatment measures and suitable control areas should be considered when field studies are planned. Study design should, for example, take into account the effects of edge, and the fact that a control area that is a habitat island may be different from a control area that is surrounded by the same habitat type. The ability to control developments such as logging and silvicultural treatments adjacent to the study area is also an important criterion for wildlife studies.

6 SUMMARY

In the long term, as the projects summarized above have shown, backlog reforestation treatments tend to replace habitats that are highly productive for many wildlife species with immature, closed-canopy conifer stands that are less productive for wildlife. In the short term, different methods used to achieve reforestation affect habitat attributes differently, and thus vary in their effect on wildlife. Silvicultural expertise can be used to create stands that have the necessary habitat elements both to meet objectives for wildlife management, and to produce timber.

Prescribed fire The response of vegetation to fire depends on a number of factors, including site characteristics, fire intensity, and the reproductive strategies of plant species present on and around the site. On dry sites or sites that are severely burned, the pre-existing vegetation is likely to be replaced by fireweed and other species characteristic of disturbed areas. On wet sites, resprouting is more likely to occur, accompanied by rapid revegetation. The degree to which small mammal abundance is reduced by fire seems to be related to reductions in the amount of vegetative cover and coarse woody debris.

Mechanical site preparation Mechanical site preparation is used to clear existing vegetation and debris, and to prepare microsites for planting. Timing of brush clearance affects the degree to which deciduous trees and shrubs resprout after treatment. That information can be used to minimize or maximize resprouting, depending on the management objectives.

Scalping initially reduces vegetation abundance by removing roots, rhizomes, and much of the stored seed pool. However, it may stimulate resprouting from the remaining root crowns, and the exposed mineral soil provides a good seedbed for pioneer species. At some sites, the advantages to seedlings resulting from scalping may be offset by increased colonization of wildlife forage species such as cottonwood, trembling aspen, birch, and willow.

Mounding machines create planting spots by scooping up a quantity of organic and mineral soil and inverting it. On some sites, mounding results in reduced vegetation competition around the seedlings for several years. Because the vegetation disturbance is limited to a small area around each planting site, mounding may be an attractive option where it is desirable to maintain the overall vegetation community.

Chemical treatments Operational applications of glyphosate can reduce overall vegetation abundance greatly, but the effect may not last longer than a year or two. Even when overall vegetation abundance has recovered to pretreatment levels, species composition may have changed. The changes in vegetation structure and species composition that follow herbicide application may reduce the quality of the habitat for some wildlife species, while benefitting others.

The variability of responses of willows to glyphosate treatment has been attributed, in part, to differences among species. New data suggest that intraspecific variability in response to glyphosate is greater than are differences among species. For example, different rates and timings of glyphosate application produce significantly different effects on willow. Glyphosate applied at 1 kg a.i./ha (about half the usual operational dosage), or in September after the formation of the abscission layer, had little effect on willow. Mid-season applications of 2 or 3 kg a.i./ha, however, resulted in shorter leaders, fewer live stems, fewer side stems, and thus less browse 1 year after treatment.

Small mammal populations are affected by herbicide applications, although they may recover, at least partially, by the second season after treatment.

Hexazinone is a water-soluble, soil-active herbicide. Because of its mode of action, concerns had been expressed about uncontrolled movement of the herbicide outside target areas. In the FRDA study, hexazinone moved as much as 60 m downslope, but always in low concentrations and in narrow strips.

Planting stock Selection of large stock types enhances conifer performance, reduces the risk of damage from small mammals, and potentially reduces the need for site preparation. It may be an effective option where wildlife concerns or other resource values make site preparation undesirable.

Conifer release cuts The potential of conifer release cuts to rehabilitate IU backlog was studied in only one FRDA northern Interior project. Many areas that were logged to IU standards in the 1950's and 1960's are superior wildlife habitat today. In the context of integrated resource management, some stands previously classified as NSR are being reassessed. These reassessments may result in more release cutting, as well as more stands classified as satisfactorily restocked. Future research projects should investigate prescriptions for release cutting that maintain habitat values as much as possible.

Control of damage by wildlife Two ongoing projects are investigating the effectiveness of herbicide treatments, alternative foods, predator odour repellents, and anti-feedant compounds in reducing damage to plantations by small mammals.

Monitoring effects of treatments on wildlife and wildlife habitat In projects designed to quantify the effects of silvicultural treatments on plantations, the response variables of greatest interest to wildlife biologists are not usually measured. To facilitate interpretations about habitat, vegetation assessments based on environmental monitoring procedures (Habitat Monitoring Committee 1990) should be used in all new projects in which treatment effects on wildlife habitat are of interest. Some studies of silvicultural treatments should also incorporate measures of wildlife occurrence, using the wildlife monitoring method developed in FRDA 1.49.

Monitoring of projects Continued monitoring of many projects is already planned, and will provide some information of value to habitat managers. Continued monitoring of willow recovery at the FRDA 1.33 (Rus) site, and of wildlife occurrence at the FRDA 1.13/1.48/1.49 site, is also recommended.

Demonstration areas Thirteen field sites were identified as having current or potential value as demonstration areas.

Planning new projects The need to address treatment effects on wildlife habitat as well as on crop tree performance should be considered when new FRDA projects are planned. Environmental (vegetation) monitoring should be incorporated into most projects and wildlife monitoring into some. Inclusion of vegetation and wildlife monitoring will affect decisions about size and layout of treatment and control areas.

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8 PERSONNEL CONTACTED

B. Bancroft, Madrone Consultants, Victoria, B.C.

L. Bedford, Ministry of Forests, Victoria, B.C.

D. Coopersmith, Ministry of Forests, Prince George, B.C.

D. Draper, Ministry of Forests, Victoria, B.C.

D. Hatler, consultant, Smithers, B.C.

L. Herring, Ministry of Forests, Prince George, B.C.

D. Kelly, FRDA Extension Forester, Prince George, B.C.

D. King, Ministry of Environment, Prince George, B.C.

T. Letchford, Ministry of Forests, Red Rock, B.C.

R. Lloyd, consultant, Smithers, B.C.

B. McLellan, Ministry of Forests, Red Rock, B.C.

R. McMinn, consultant, Victoria, B.C.

F. Milinazzo, Ministry of Forests, Burns Lake, B.C.

G. Milne, Ministry of Environment, Smithers, B.C.

R. Richards, Ministry of Forests, Prince George, B.C.

M. Spike, Northwood Pulp and Timber, Prince George, B.C.

T. Sullivan, University of British Columbia, Vancouver, B.C.

C. Sutherland, Ministry of Forests, Williams Lake, B.C.

S. Taylor, Forestry Canada, Victoria, B.C.

R. Trowbridge, Ministry of Forests, Smithers, B.C.